The 17th Annual David S. Snipes/Clemson Hydrogeology Symposium Field Trip Guidebook

Geologic Investigation of the Cashiers and Highlands, NC Area

Whiteside Mountain from the south

Field Trip Leaders: William Burton, USGS and Scott Brame **April 1/3, 2009**

Geologic Investigation of the Cashiers and Highlands, NC Area

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Abstract

The Highlands-Cashiers area boasts numerous exfoliated domes and headwalls that create a unique geomorphologic setting with impressive scenery. The resulting topographic expression is the result of a complex sequence of large scale intrusion, migmatization and metamorphism.

The dominant landform and centerpiece of this area is Whiteside Mountain (figure 1). The 1000 foot plus cliff face on the south side attracts both rock climbers and wealthy vacationers.

The prominent cliff faces are composed of a mixture of Whiteside trondjemite and the Ashe Metamorphic suite. The Whiteside pluton intruded synchronously with deformation of the metamorphic rocks during the Taconic orogeny (470 to 440 Ma).

Figure 1. Aerial view of Whiteside Mountain

Introduction

The majority of this field trip focuses around the work done by William Burton (2007) and his publication "Bedrock Geologic Map of the Headwaters Region of the Cullasaja River, Macon and Jackson Counties, North Carolina". The text that accompanies this map is attached as a stand-alone publication after the descriptions of the field trip stops. Refer to this publication for detailed explanations of the geology. The relation of the mapped area (white polygon referred to as the Headwaters) to the large scale regional geologic features is shown in Figure 2.

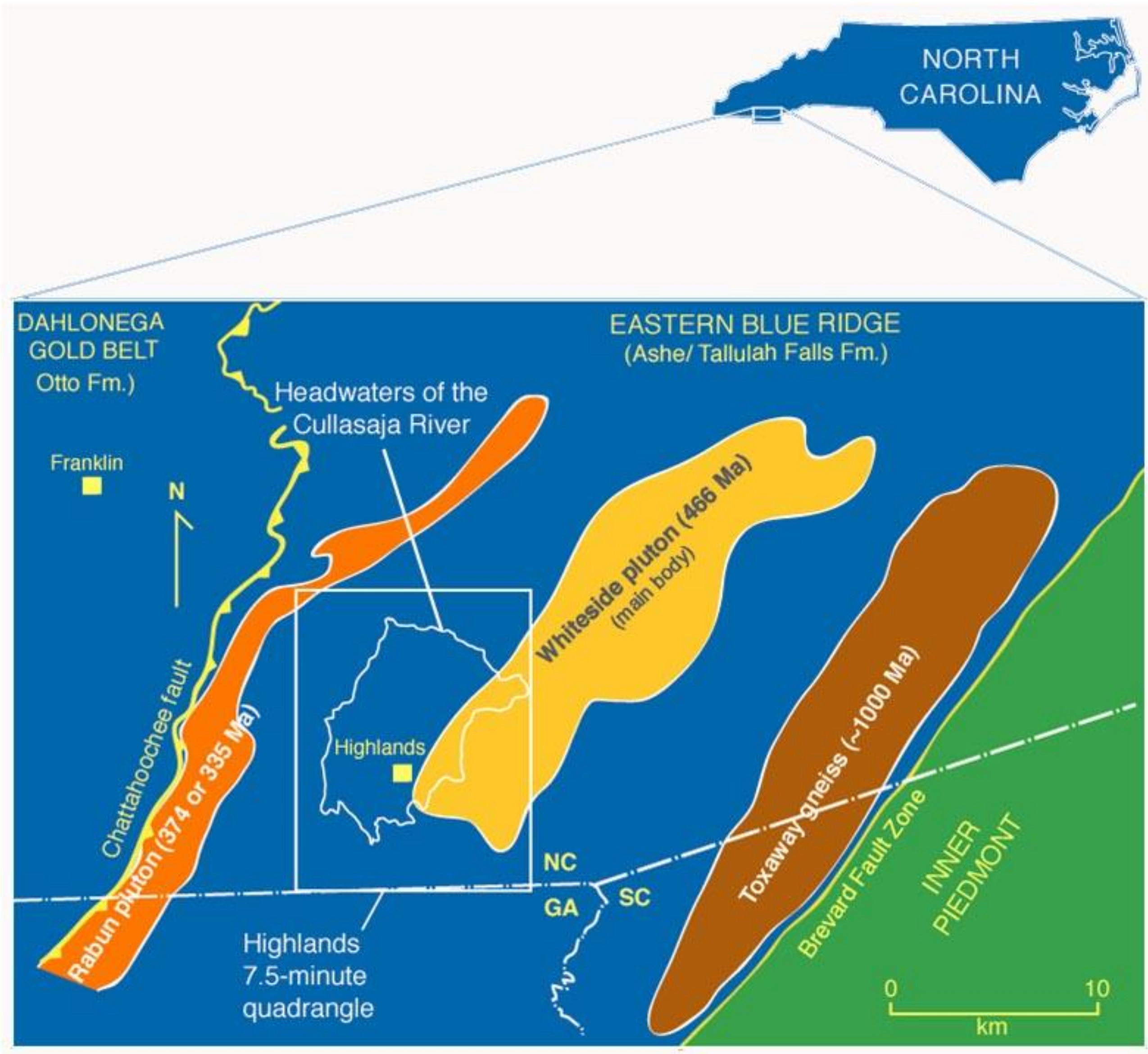

Figure 2. Geologic setting of mapped study area. (from Burton and Kunk, 2006)

Tectonic History

The rocks in this area exhibit several phases of folding and a single dominant, prograde metamorphic event that was possibly overprinted by a second, less pervasive prograde event (Burton, 2007). An age of 466 Ma has been proposed for the Whiteside pluton (Miller et.al, 2000). If this is correct and the pluton intruded synchronously with deformation of the country rocks, then deformation and metamorphism occurred during the Taconic orogeny (470 to 440 Ma).

Burton and Kunk (2007) sampled rocks within the study area and determined ages for mica and amphibole in the rocks using an argon dating method. The results suggest that the minerals formed in the period during or before 319-309 mybp, which are ages typical of the later Alleghenian orogeny. The results of the dating are shown in figure 3. These younger ages contrast with other geochronologic and field evidence that indicate Taconian (about 465 Ma) intrusion, deformation and metamorphism. The authors' preferred interpretation for the younger dates is that they reflect a prolonged burial and post-peak-metamorphism cooling following the Taconian orogeny, which was suddenly terminated by upthrusting on the underlying Chattahoochee fault during the Alleghanian orogeny.

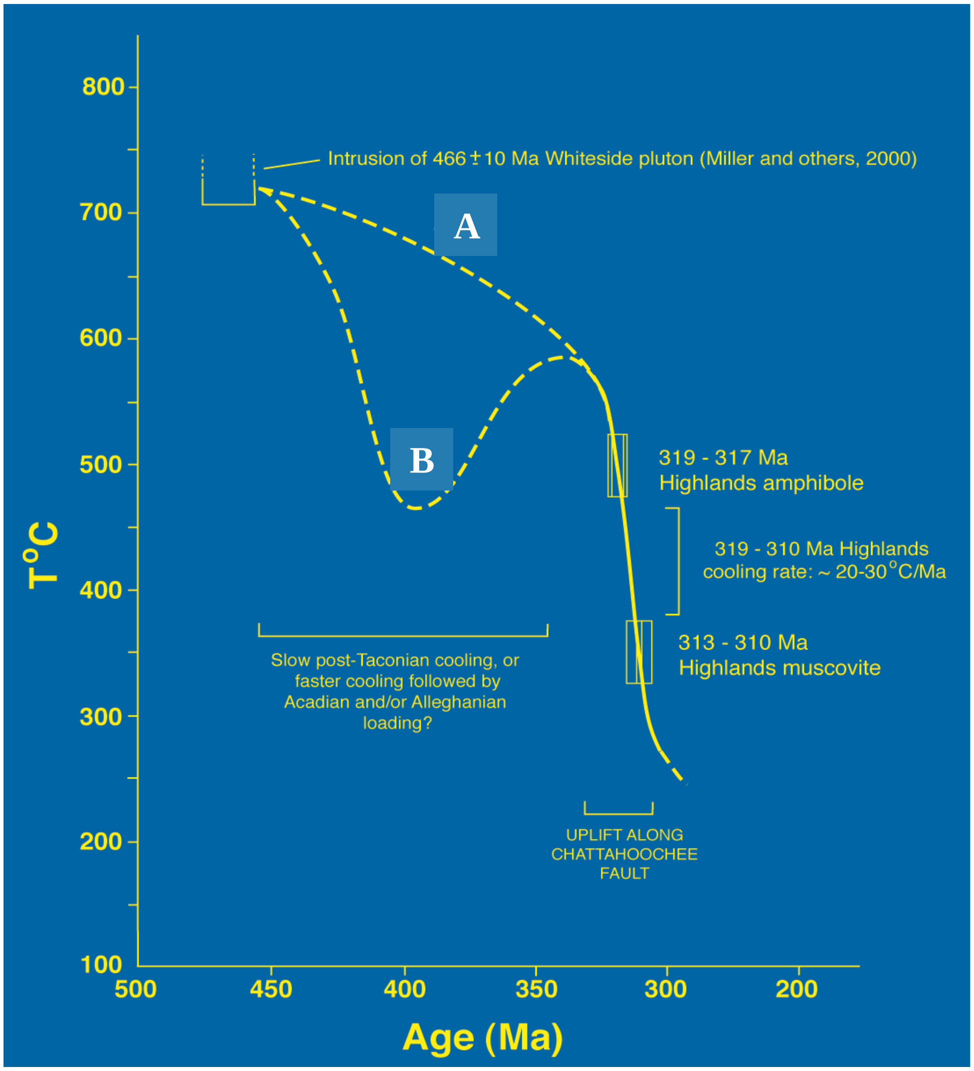

Figure 3. Age of intrusion and sample dates using Ar/Ar dating (from Burton and Kunk, 2006).

Deformational History

Two generations of foliation and three major phases of folds are recognized. The second- and third- generation folds trend northeast and exert the most control on regional foliation trends. Since the orogeny, the region has undergone uplift, fracturing, and erosion. In figure 4 the major fold axes are shown along with their generation history. The first generation folds (F1) have been mostly obscured by second (F2) and third generation (F3) folds. The geologic units are defined later in figure 9.

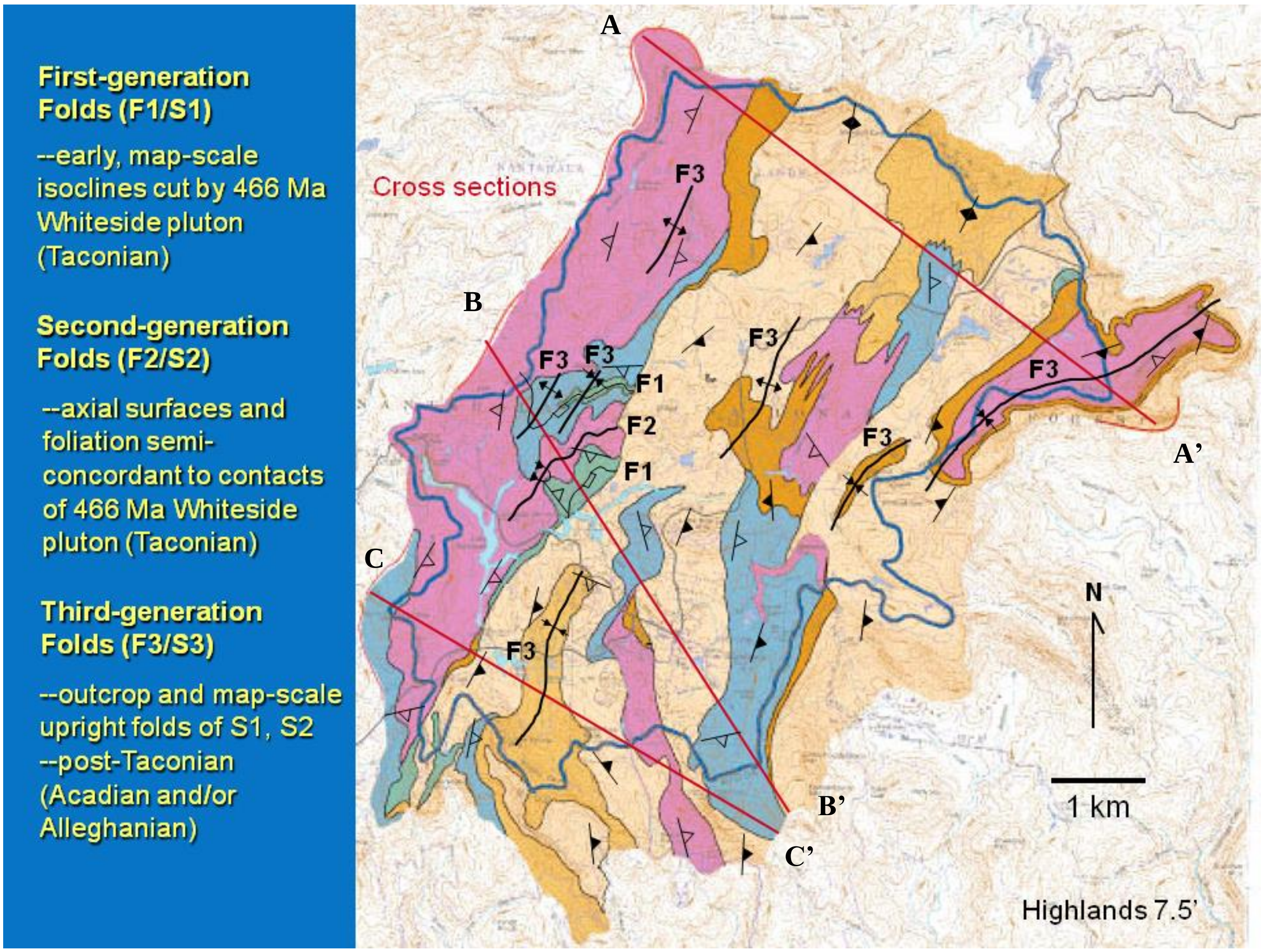

Figure 4. Major fold axes occurring in the Burton study area (from Burton and Kunk, 2006).

In figure 5, the cross sections defined in figure 4 are presented. The timing of the Whiteside intrusion was post-F1, syn-F2, and pre-F3. The intrusion took the form of east-dipping, sheet-like bodies semi-concordant to regional S2 and F2 axial surfaces. Everything was later folded by F3. Table 1 summarizes the tectonic and deformational history.

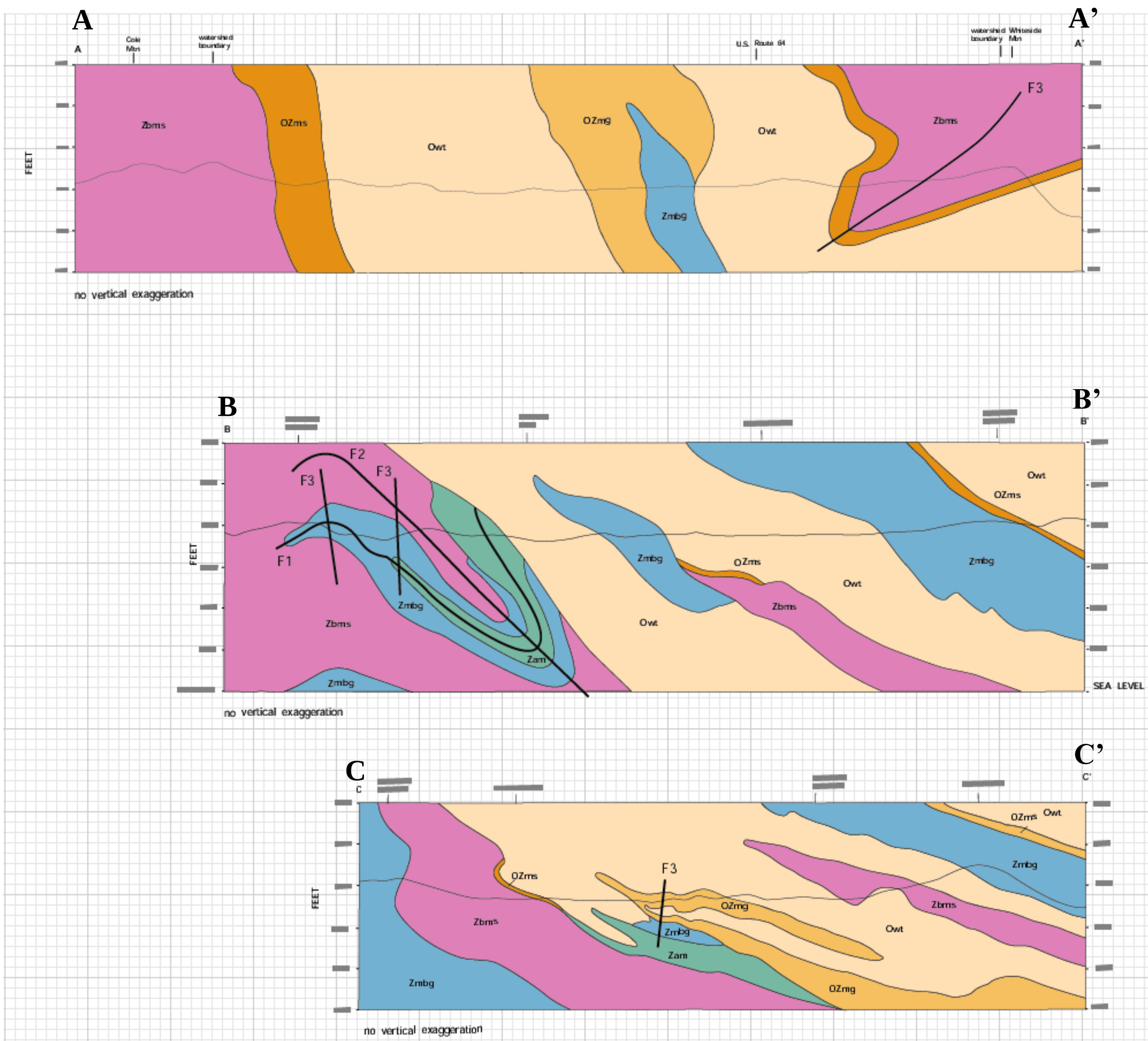

Figure 5. Cross sections through Burton study area (from Burton and Kunk, 2006).

Table 1: Chronology of tectonic events (from Burton and Kunk, 2006).

Date	Deformational Event
470+ Ma	Development of east-west-trending (present orientation) isoclinal folds during kyanite-zone metamorphism (Taconian orogeny)
465 Ma	Northeast-trending, northwest-verging F2 folds, accompanied by sheet-like intrusion of Whiteside pluton, during sillimanite-zone metamorphism (Taconian orogeny)
Acadian/ Alleghanian?	Northeast-trending, upright F3 folds; slow cooling from Taconian peak
320-310 Ma	Rapid cooling, uplift along underlying Chattahoochee thrust (Alleghanian orogeny)

Field Trip Road Log and Stops

In addition to the areas mapped by Burton, a few other field trip stops have been included because they either add some unique geologic aspects or are worthy natural features. The locations of the field trip stops are shown in Figure 6.

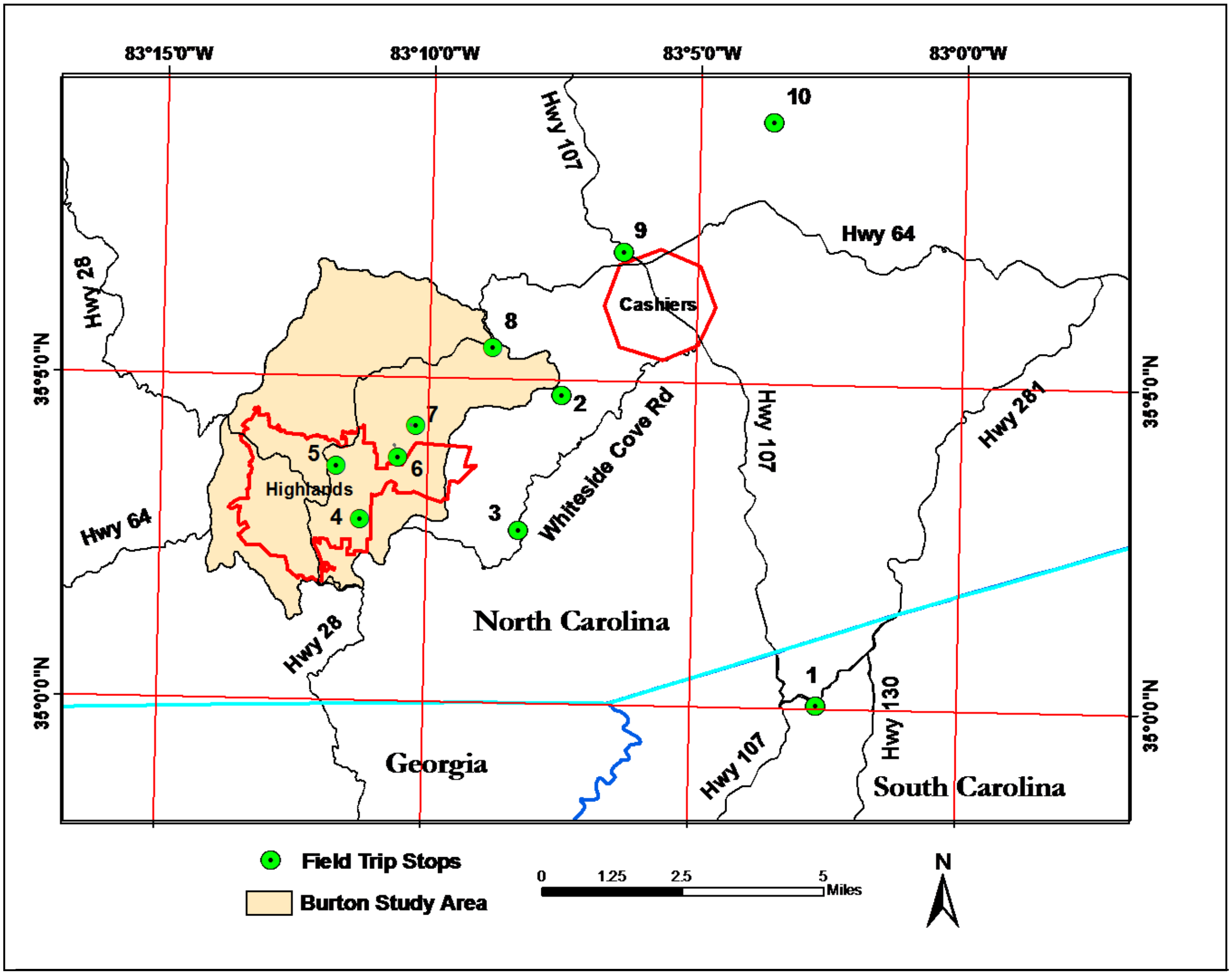

Figure 6. Location of field trip stops in relation to the area mapped by Burton (2007) and the municipalities of Highlands and Cashiers, NC.

The relationship of the stops to the regional geology is shown in Figure 7. The geologic units in this map are derived from Thigpen, Hatcher and Settles (2006). While the unit names and contacts differ somewhat from the Burton (2007) map, they are used in this guide to show the correlation with the Burton nomenclature. For example, the Tallulah Falls formation is the local equivalent of the Ashe Metamorphic Suite in the Burton report.

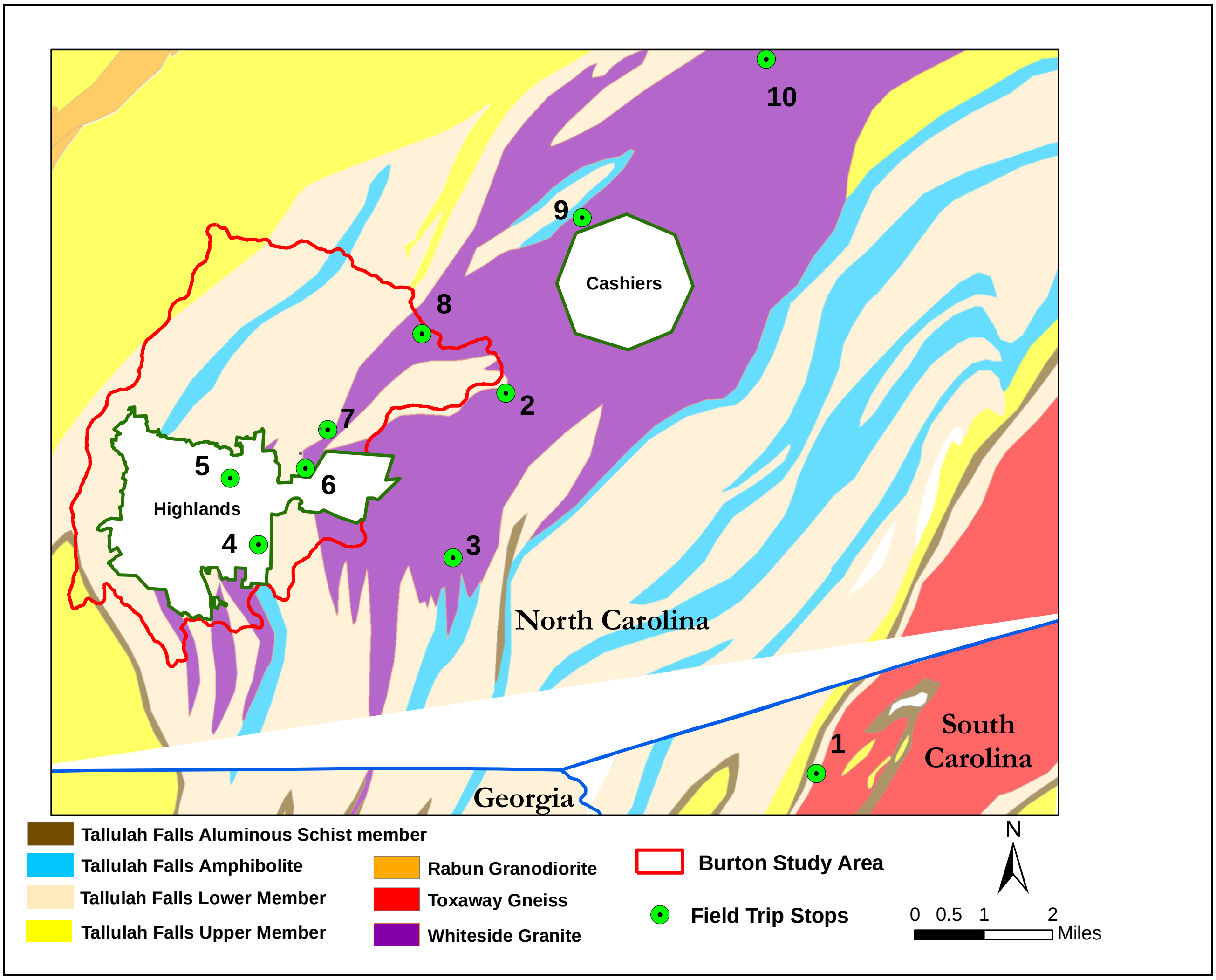

Figure 7. Location of field trip stops overlaid with regional geologic features from Thigpen, Hatcher and Settles (2006).

Departing from the Madren Center parking lot on the Clemson University campus, turn left at the entrance and drive to Perimeter Road. Turn left on Perimeter Road and proceed to SC Hwy 93. At the T intersection, take a left and drive west on SC 93 to the intersection of U.S. 76/123 (SC 93 ends here). Turn left on 76/123 and proceed about 1 mile west to the Old Seneca Hwy intersection (now replete with a Blooms Grocery store and Palms gas station).

0.0 Miles: The intersection of Hwy 76/123 and the Old Seneca Hwy

3.3 Miles: Intersection of Old Seneca Hwy and Hwy 130. Turn right and go north on 130.

4.7 Miles: Keowee Lake dike. Note the town of Newry off to right and that it is topographically lower than the lake level.

10.8 Miles: SC 130 takes a right turn at this intersection (has a stoplight). Stay on 130.

20.0 Miles: Hwy 11 intersection. Go straight on Hwy 130.

29.4 Miles: Intersection of SC 130 and Wigginton Road.

29.9 Miles: Bad Creek entrance on right.

30.5 Miles: Forest Service dirt pullout on right. Park here for Stop 1.

The Foothills Trail crosses SC 130 at this pullout. Proceed across the road (going westerly) and follow the Foothills trail (uphill) about a hundred yards till you come to large boulders in the trail.

Stop 1: Toxaway Gneiss

The boulders in the trail and in the ravine uphill of the trail are composed of the Toxaway Gneiss. These rocks are of Grenville age (1.1 billion years old) and have been dated using zircons. The Toxaway Gneiss is a strongly foliated granitic gneiss with abundant plagioclase and K-spar. This gneiss does not exhibit the strong lineations observed in Piedmont such as in the Henderson Gneiss.

This exposure is located on the west side of the NE-SW trending Toxaway dome structure. The dome is flanked on all sides by rocks of the Tallulah Falls Formation. The Toxaway dome in its general outcrop pattern is an elongate feature that has a steeply northwest-dipping northwest limb and a more moderately inclined southeast limb (Hatcher, 1977).

The dome structure is somewhat of a riddle in that its geologic relations are not well understood. The entire structure might be “rootless” and appears to have been punched up through the surrounding rocks. As with the country rock, it was most likely transported some distance from the east.

Note: This stop is located 0.1 mile short of the entrance to Whitewater Falls. These falls dramatically expose about 400 feet of the Toxaway Gneiss.

After returning to your vehicle, head back down SC 130 in the direction you previously came (i.e., to the south).

31.6 Miles: Intersection of SC 130 and Wigginton Road. Go right on Wiggington Rd.

32.9 Miles: Large Outcrop on right. Pull into large parking lot on left.

Optional Stop: Views of Piedmont and Tallulah Falls formation

To the east is a nice view of the Piedmont, Lake Keowee and the Bad Creek Pumped storage plant and reservoir. Across the road are exposures of the Tallulah Falls formation (also

33.8 Miles: Intersection of Wigginton Road and SC Hwy 107. Turn right and head north on 107.

34.8 Miles: Enter North Carolina

41.2 Miles: Whiteside Cove Road on left. Take a left and proceed west on Whiteside Cove Road.

43.9 Miles: Cross Chattooga River. The headwaters of the Chattooga begin on the north side of Whiteside Mountain at Devil's Courthouse.

44.2 Miles: Grimshawes Place on right. Canadian Thomas Grimshawe was the first man of European descent to settle Whiteside Cove in the 1800s.

44.4 Miles: Peregrine Development road on right. Turn right and proceed up the hill.

45.2-45.3 Miles: Whiteside trondhjemite exposed in roadcut

45.5 End of road. Trail on left leads to view of Whiteside Mountain.

Stop 2: Viewpoint of south side of Whiteside Mountain

The Whiteside Granite was first named by Arthur Keith (1907), who named it after the cliff exposures on Whiteside Mountain just to the north of here. Olson (1952) reported it to be intrusive in origin and felt it was late Paleozoic in age. For a variety of reasons, including semi-conformable field relations with the other stratified units, its locally gneissic character, and the roundedness of zircons in the rock, McKniff (1967) concluded that it was originally a stratified felsic volcanic rock, and Precambrian in age. Miller and others (1997) cited the presence of igneous foliation, aplite and pegmatite dikes, country-rock enclaves, and migmatitic contacts between the Whiteside and other rocks as proof for an intrusive origin, and noted variability in grain size and foliation development in the rock as evidence that the intrusion occurred during regional deformation. Geochemical analyses by Miller and others (1997) showed it to be mostly trondhjemite with minor granodiorite. Their U-Pb analyses of zircon rims using the SHRIMP technique yielded a crystallization age of 466 +- 10 Ma (Ordovician); cores from the same zircons yielded Mesoproterozoic and older ages, indicating that the intrusion encountered ancient crust at depth.

The south face of Whiteside is notable in that the contact between the intrusive plution (Owt) and the country rock (Zbms) can be clearly observed. The contact occurs near the base of the sheer cliff face as shown in the topographic map in figure 8. A photo of the cliff face with the two rock types is shown in figure 9. The rounded, smooth exfoliated dome in the foreground on the right (in figure 9) is characteristic of the manner in which the Whiteside trondhjemite weathers: a fairly smooth face with occasional water grooves. In contrast, the upper cliff face of Whiteside is composed of the Ashe Metamorphic Suite (AMS) and weathers very differently. The AMS has a pronounced foliation that is dipping slightly to the north and during weathering the foliation creates a mottled surface of ledges and noticeable features.

This difference in rock types is well known by the rock climbers that scale this large wall. The exfoliated dome offers very few natural handholds or footholds and a technique called friction climbing must be used. In contrast, the upper face of Whiteside contains numerous large, well developed features that offer ample handholds and footholds. The country rock in essence makes Whiteside a slightly easier climb than some of the pure exfoliated dome climbs, though slightly easier is a relative term.

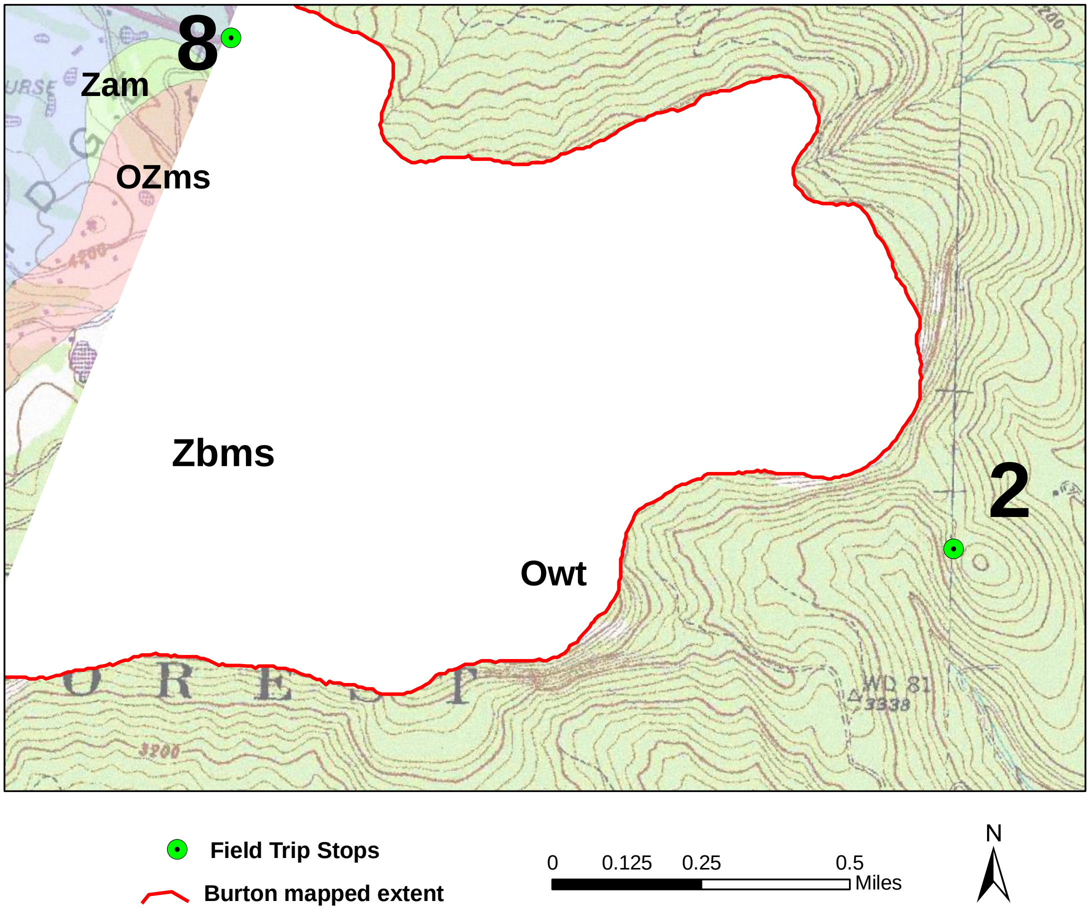

Figure 8. Topographic map of area observed from Stop #2.

The imposing south face of Whiteside Mtn was first ascended in 1971 over two days by a four man team led by Dr Peter Young of Tennessee. The climbers ascended in a very bold style, placing only a handful of expansion bolts to compliment the scarce protection available in the rare flake or pocket. This ascent set the tone for all future climbing in the Cashiers Valley: ground up ascents of new routes, minimal bolting done on lead in the crackless rock, and long, dangerous runouts. As a result the area was visited by only small numbers of expert climbers despite the vast amount of rock faces present. However, since 1971, hundreds of climbing routes have slowly but steadily been established on the exfoliated domes in Cashiers Valley by a relatively small group of climbers. The climbing is primarily face and friction climbing with routes range in length from 500 -1000 ft. All are considered very difficult.

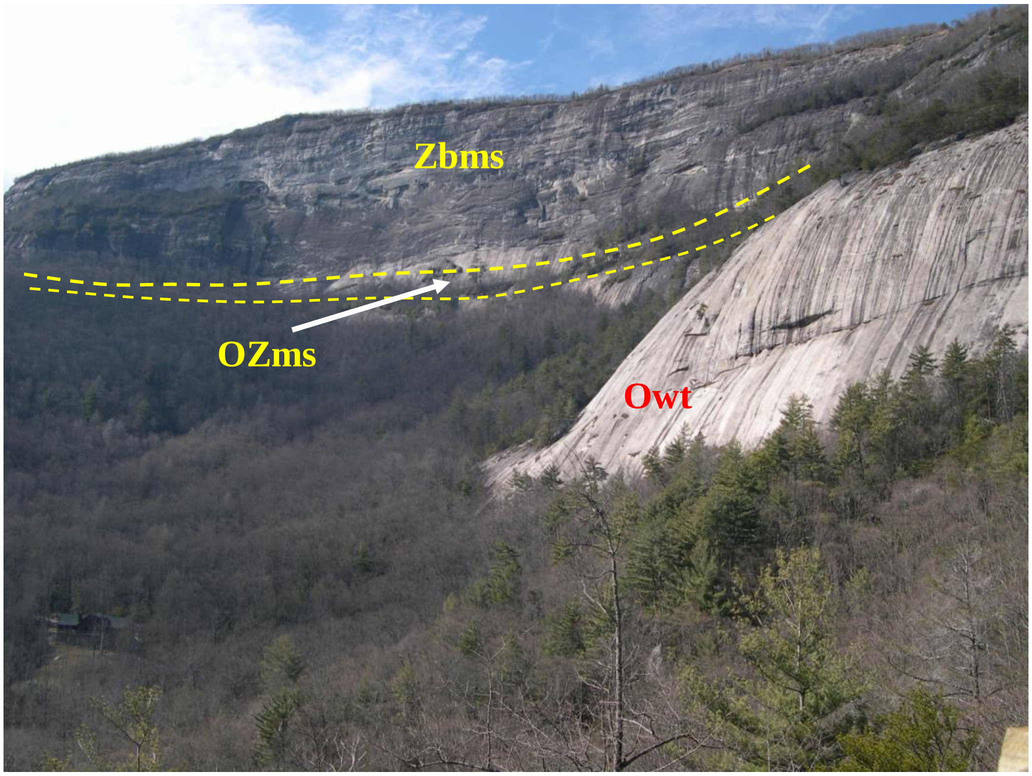

Figure 9. South face of Whiteside Mountain with dotted line showing approximate contact between the Ashe Metamorphic suite above and the Whiteside trondhjemite below. The different weathering nature of the pluton and metamorphic country rock can be observed from this viewpoint.

From this stop proceed back down the hill to Whiteside Cove Road.

46.6 Miles: Turn right on Whiteside Cove Road.

47.4 Miles: Grimshawes Post Office. Named after Thomas Grimshawe, it is billed as the smallest post office in the US at 6 feet by 8 feet. This post office was established in 1875.

48.2 Miles: "Big View" of Whiteside Mountain from the south. From this viewpoint you can see the southside as well as the Wildcat Cliffs section to the west.

49.8 Miles: Park in small pull-off on right.

Stop 3: Granite City

A short, but steep trail leads from the Whiteside Cove Road to an outcrop of Whiteside trondhjemite that is highly fractured into prominent joint sets (figure 10). This outcrop is located on an extension of a south running ridge spur of Blackrock Mountain.

The outcrop is a set of blocks that have broken and spalled away from a near vertical headwall (McGraw, 1982). The headwall is a extended feature of the exfoliated dome of Blackrock Mountain. The boulders are fractured into vertical joints that are atypical of the exfoliated domes

found in this valley. These joints formed when the in-situ stresses were lowered as the blocks broke from the headwall. This degree of fracturing is not observed in un-spalled rock.

Figure 10. Mark Lassiter in one of the large joints at Granite City.

51.8 Miles: View of Black Rock on right.

52.9 Miles: Rich Gap Road on left (FS Road 101). A parking lot about 50 yards up this road can be used as a trailhead for a short walk to see two 400 year old virgin poplar trees called the Padgett Trees (figure 11).

Figure 11. Plaque for Bob Padgett Poplar Trees.

53.6 Miles: Old quarry on left with exposures of Whiteside tronhjemite.

55.1 Miles: Sunset Rock road on left. Drive up road to parking lot.

All of the stops that occur in the area mapped by Burton (2007) are shown in figure 12.

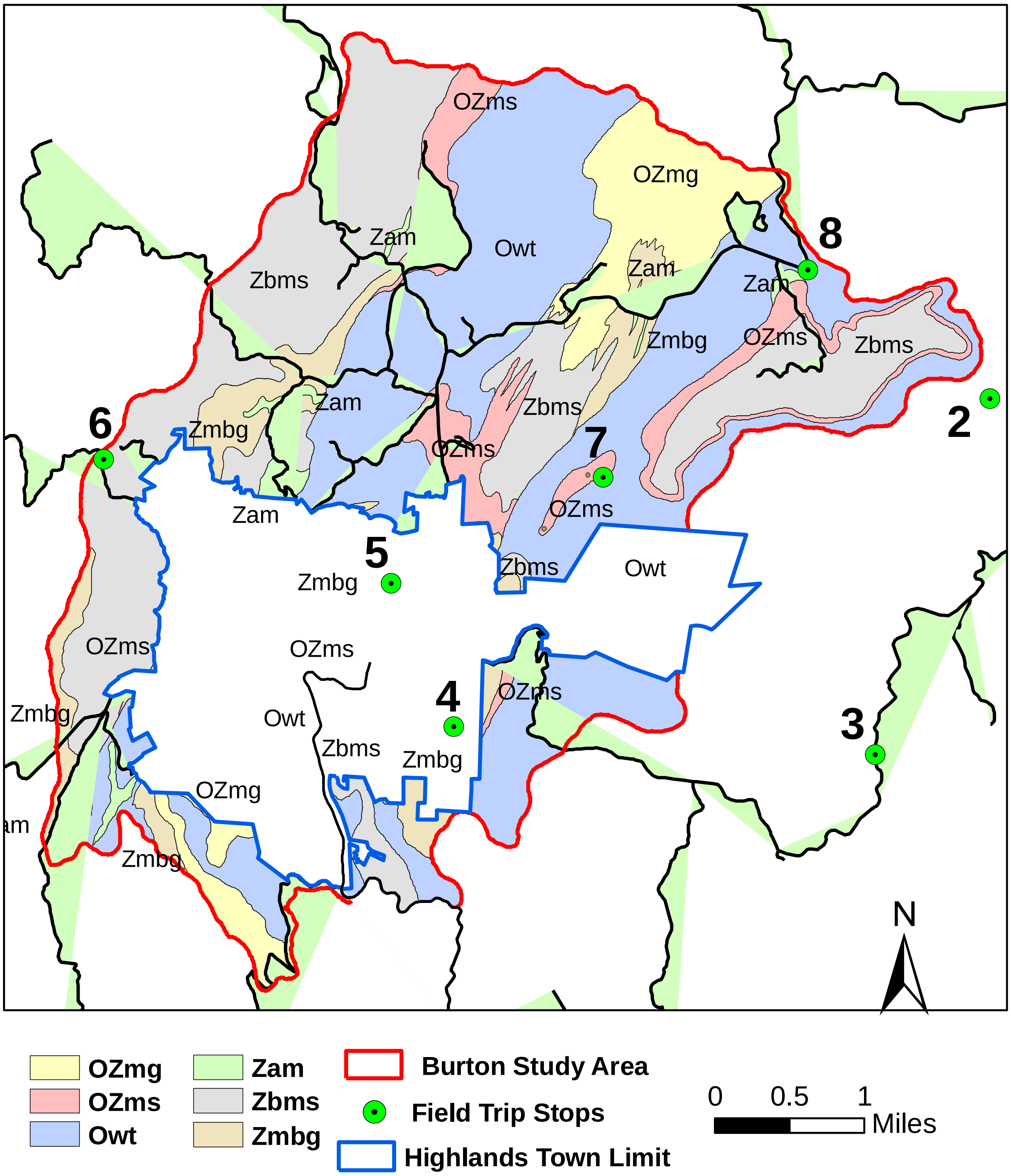

Figure 12. Location of stops that contained in the Burton (2007) mapped area.

Stop 4: Sunset Rock

This scenic overlook (figure 13) owned by the town of Highlands is composed of the Ashe Metamorphic Suite, named by Abbott and Raymond (1984) after the Ashe Formation of Rankin (1970), a large belt of metasedimentary and metaigneous rocks in the eastern Blue Ridge of North Carolina and northern Georgia, and also known in this region as the Tallulah Falls Formation of Hatcher (1971, 1978). The suite is considered to be Neoproterozoic in age based on stratigraphic correlation with other formations to the north, and it perhaps originated as deep-water sediments and mafic volcanics deposited on oceanic or transitional oceanic-continental crust at a passive continental margin (Abbott and Raymond, 1984). This rock was mapped as muscovite-biotite gneiss (unit Zmbg on map), and it probably originated as a sandy marine sediment before deformation and regional metamorphism.

Figure 13. Sunset Rock overlooks the town of Highlands, NC.

The rock has two foliations in it (figure 14): the first one, S1, is represented by the mm- to cm-scale quartzofeldspathic compositional layering, or gneissosity, that is the dominant fabric in the outcrop. The trend of the foliation is northeast and steeply dipping, roughly parallel to the trend of the major lithologic belts in the area. The second foliation, S2, is nearly parallel to the first and is in the form of a schistosity, represented by coarser-grained muscovite and biotite, that locally overprints the gneissosity and is therefore younger. This schistosity is accompanied by small granitic-looking lenses and stringers that suggest that the schistosity formed under conditions of partial melting, perhaps during intrusion of the Whiteside pluton. Both foliations are thought to have formed in the Ordovician during the Taconian orogeny, also the time of intrusion of the Whiteside. S2 is locally folded by small, gently-north-plunging F3 folds. The lack of extensive jointing in the rock is typical for most lithologies in this area, with the possible exception of amphibolite. The view to the west

shows nearly the entire Upper Cullasaja watershed, which is a perched, relatively low-relief headwaters watershed typical of many in the Blue Ridge

Figure 14. S1 and S2 foliation in the Ashe Metamorphic Suite at Sunset Rock

55.6 Miles: Intersection of Horse Cove Road and US Hwy 64. Proceed straight at light going west on Hwy 64.

58.0 Miles: Pull off in parking area on right next to a dramatic roadside waterfall.

Stop 6: Bridal Veil Falls

This scenic waterfall is cutting through garnetiferous mica schist (Zbms in figure 12). A close examination of the rock reveals that is grades back and forth from schist to a more gneissic character. A photomicrograph of the schist under crossed polars is shown in figure 15. The schist contains abundant mica (both muscovite and biotite) plus quartz and garnet.

In 2005 a large piece of the under hanging wall dislodged and left a large boulder in the road that goes underneath the falls (figure 16). This was removed sometime in 2008. The fresh rock revealed by the rockfall displayed a sulfurous yellow coating in March 2009.

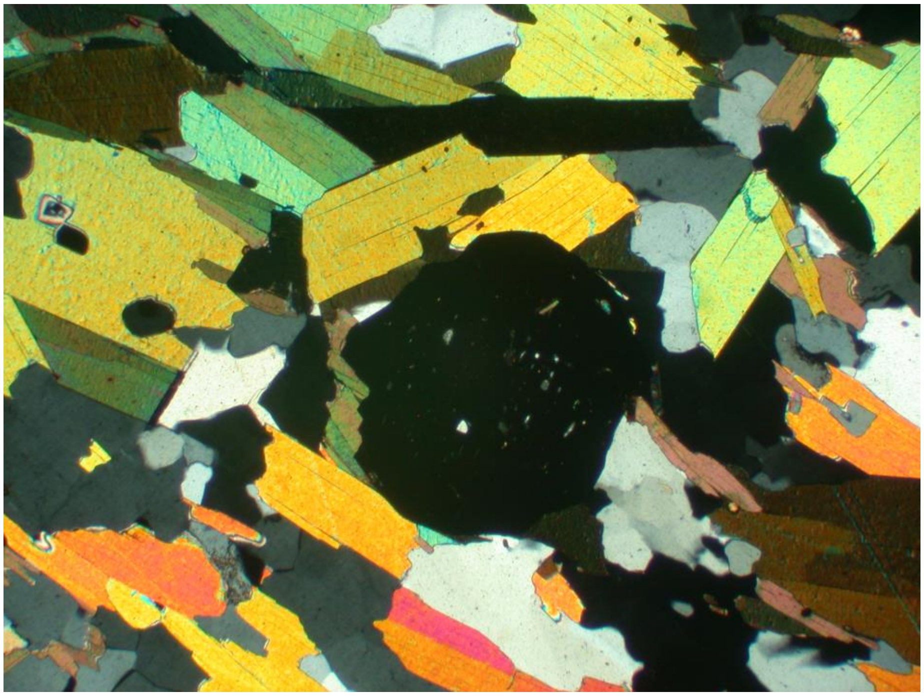

Figure 15. Microphotograh of thin section of schist at Bridal Veil Falls (photo by R. Warner)

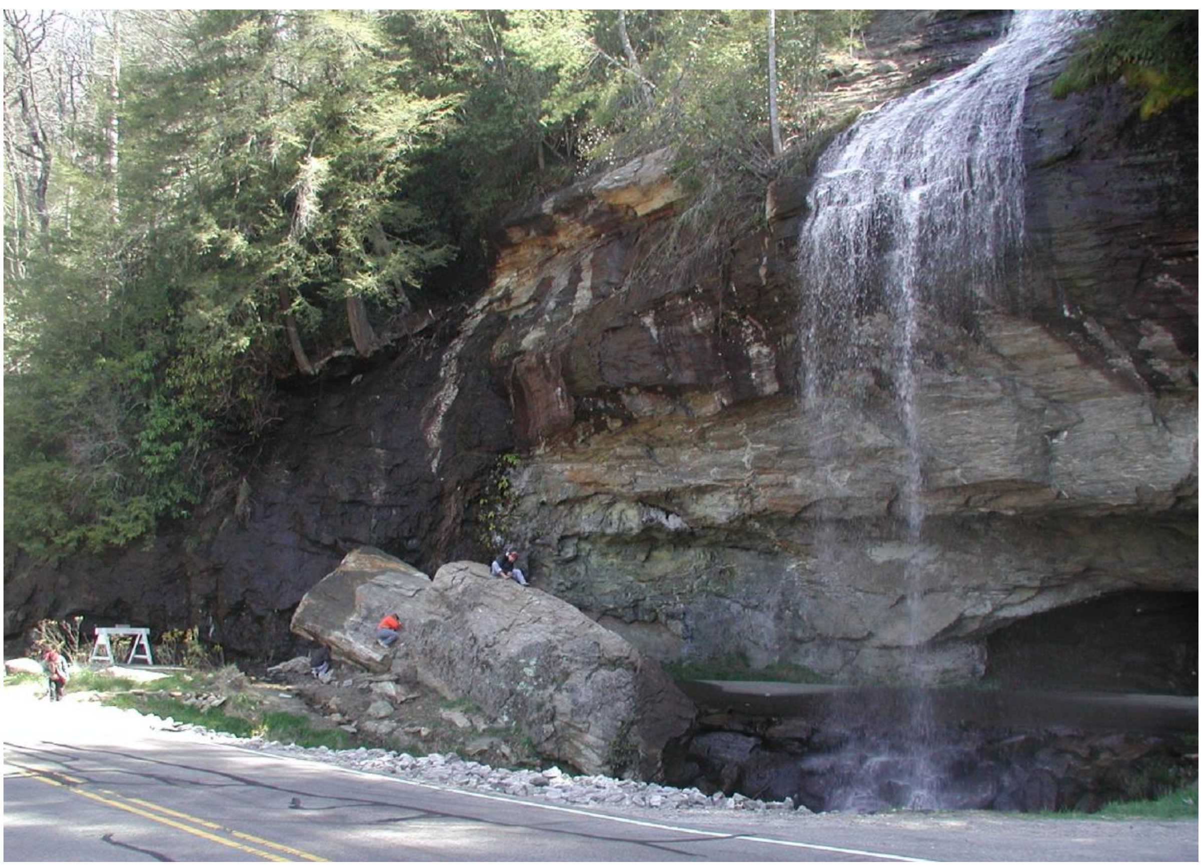

Figure 16. Bridal Veil Falls with large rockfall that occurred in 2005. (photo by Richard Warner)

From the falls, head back east on Hwy 64 towards Highlands.

60.5 Miles: Hwy 64 turns left at light. Stay on 64 going east.

61.1 Miles: Turn right on Poplar Street. Proceed 0.1 miles to Highland town quarry and municipal yard.

Stop 6: Quarry on south side of Little Bearpen Mountain

This quarry exposure of the Whiteside pluton shows its generally massive, weakly jointed character and distinctive light gray appearance (figure 17). The Whiteside is most accurately termed a trondhjemite because plagioclase is the dominant feldspar and potassium feldspar is generally less than ten percent of the rock, which helps explain why its color is gray rather than pink like typical granite. Biotite and muscovite mica are also typically less than ten percent. The degree of development of tectonic foliation in the Whiteside is variable, as can be seen in this exposure, which suggests that it was still in the process of intruding and had not completely solidified when regional deformation occurred. However, the Whiteside does locally crosscut the first-generation foliation (S1) and first-generation folds (F1), and evidence at other outcrops suggests that it intruded during the formation of S2/F2, and was locally folded by F3. In the cross-section interpretation of this map the Whiteside is therefore represented as a sill- or sheet-like body broadly conformable with the surrounding lithologic belts into which it intruded.

Figure 17. Whiteside trondhjemite at Highlands town quarry.

From this stop head back to Hwy 64 and proceed east (towards Cashiers).

64.4 Miles: Turn right into gate for the Cullasaja Club. Prior permission is needed to enter.

Stop 7: Cullasaja Club

This outcrop is mapped as biotite-muscovite migmatite schist (OZms, orange-ish colored unit in figure 18), and represents schist of the Ashe Metamorphic Suite near its contact with Whiteside trondhjemite (Owt, pinkish colored unit in figure 18). The rock is named migmatite (or mixed rock) because of the numerous light colored layers that are interleaved with the darker layers of the schist. The granite-like layers are compositionally similar to the Whiteside and formed either throught in situ partual melting of the schist during nearby intrusion of the Whiteside or by direct intrusion of thin sills of Whiteside magma between layers of the schist. The map label reflects this hybrid origin: O represents the Ordovician age of the intrusion that gave the rock its migmatitic character, and Z represents the original, Neoproterozoic age of the intruded rock.

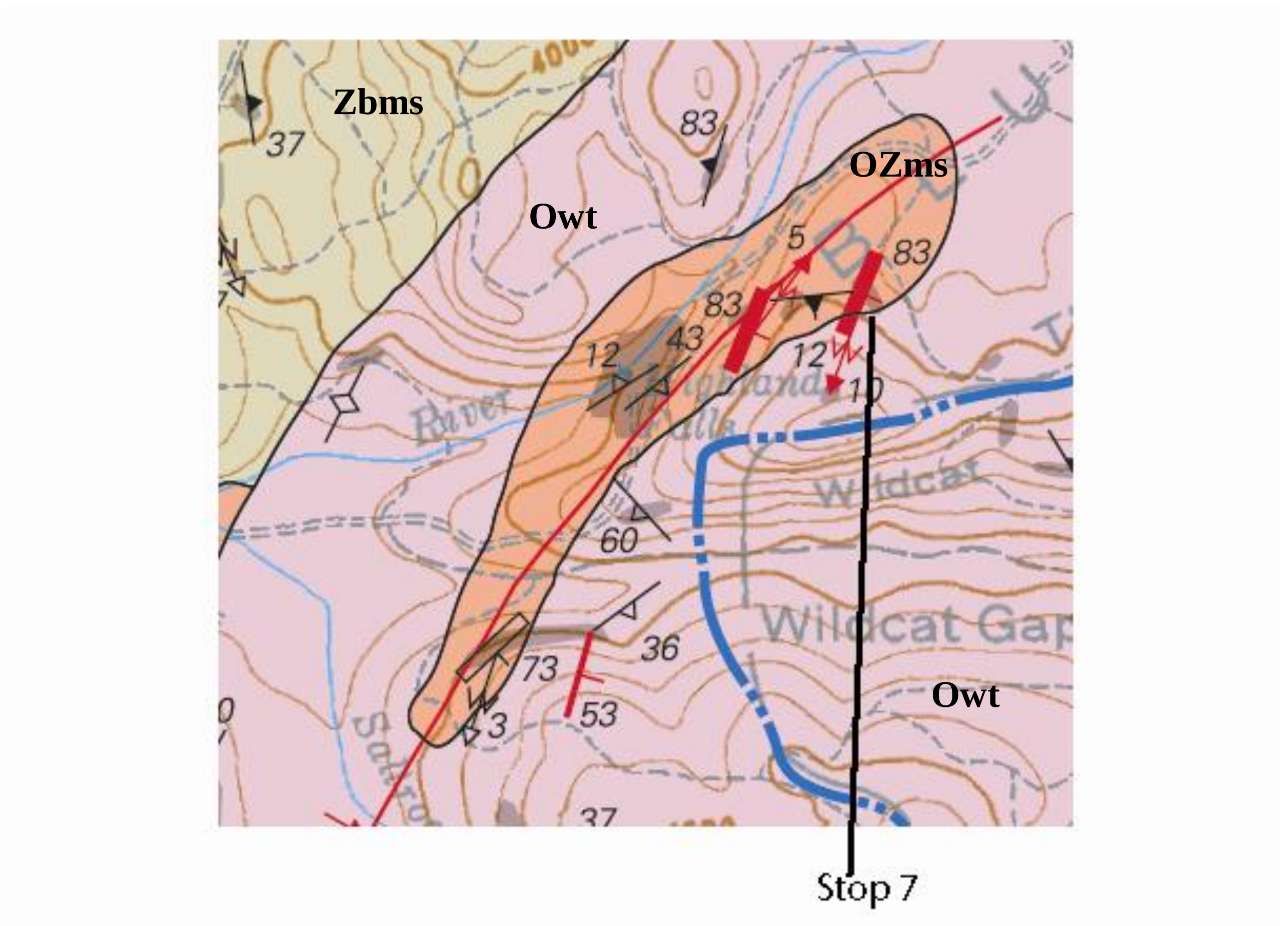

Figure 18. Location of Stop 7 in relation to Burton (2007) mapped units.

The outcrop displays beautifully the sharp, upright folds that are characteristic of F3 folds (figure 19) in the map area. These folds formed after the main, regional S1/F1 and S2/F2 Orodvician metamorphic and deformational events. Gently-plunging to upright F3 folds locally exert a strong influence on the lithologic map pattern in this area, including Whiteside Mtn. itself, which is an F3 synform in migmatitic schist (OZms) surrounded by Whiteside trondhjemite (Owt) and named on the map the Whiteside Mtn. synform.

Fig 19. F3 folds in migmatite schist at roadcut in Cullasja Club community.

The roadlog mileage assumes that you did not enter the development and returned to Hwy 64.

65.7 Miles: Pull off on right just after passing turnoff to Whiteside Mountain Road on right.

Stop 8: Cowee Gap overlook

This sweeping view has an excellent view of the north side of Whiteside Mtn. (figure 20), including the subhorizontal contact between biotite-muscovite schist (Zbms) country rock above and Whiteside trondhjemite (Owt) plutonic rock below of the Whiteside Mtn synform. The contact between the two lithologies is marked by a thin layer of migmatite (OZms). Off to the east are more cliffs of similar plutonic rock, which likely also represent sheet-like intrusions into the broad belt of

Ashe Metamorphic Suite/Tallulah Falls Fm. A topographic map of this area was previously shown in Figure 5.

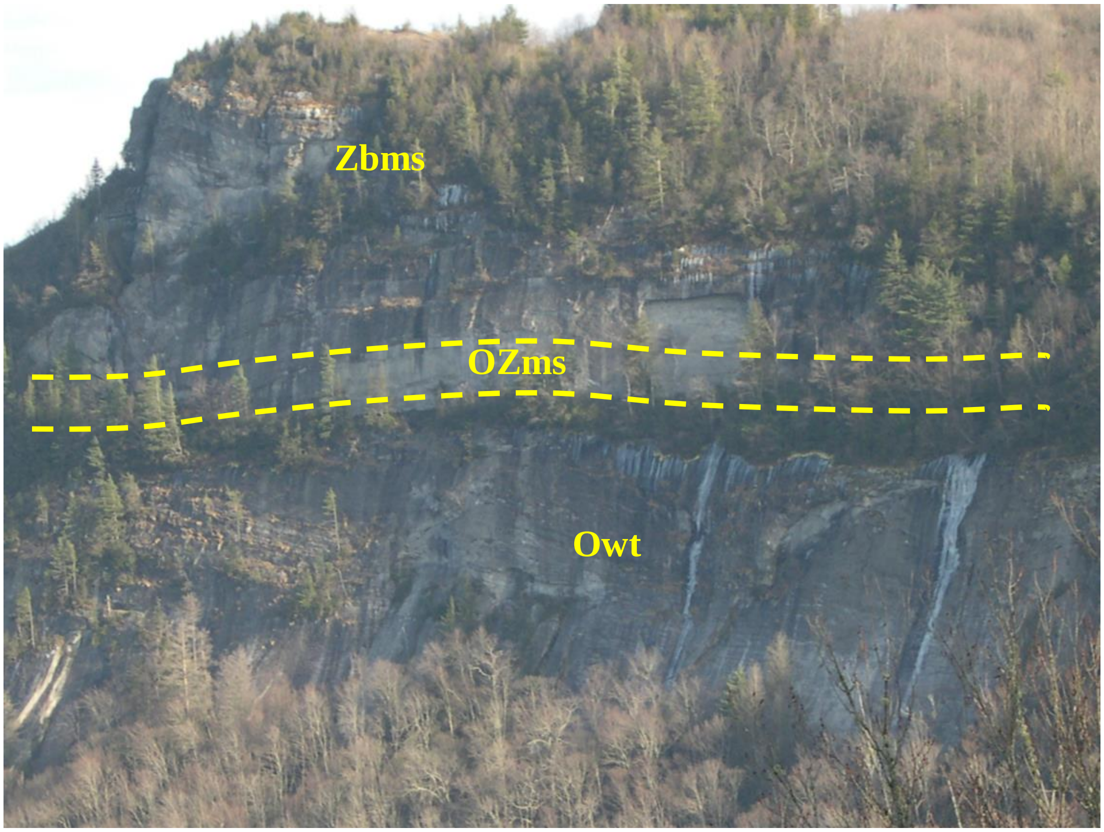

Figure 20. View of north side of Whiteside Mountain from Cowee Gap (Hwy 64).

From this stop, proceed east on Hwy 64.

70.5 Miles: Intersection of Hwy 64 and SC Hwy 107 in Cashiers (pronounced kash-urs), NC. The area on Hwy 64 east of Cashiers is referred to as Sapphire Valley.

Stop 9 (optional): Cashier Gneiss Type Locality for McKniff (1976)

From the above described intersection take a left and proceed 0.4 miles north on Hwy 107 to a quarried outcrop of Whiteside trondhjemite. This outcrop is very similar in nature to the Highlands town quarry. This site was used by McKniff (1967) as a type locality for the felsic intrusive rock he described and labeled the Cashiers gneiss. A visit to this site is noteworthy in that the rocks displayed here are remarkably similar in appearance to the trondhjemite observed at the Highlands Town quarry.

If skipping Stop 9, proceed straight at the intersection and continue east on Hwy 64. If skipping stop 9 and 10, turn right at intersection going south on Hwy 107.

72.0 Miles: Expansive section of a newly exposed roadcut of Whiteside Trondhjemite.

73.1 Miles: Turn left into the Lonesome Valley development. Entry into this area is by prior permission only.

Stop 10 (optional): Views of Laurel Knob

Laurel Knob is the tallest cliff in the eastern United States, sporting climbing routes over 1200 ft in length. This exfoliated dome composed of Whiteside trondhjemite is well known by rock climbers for its trademark water grooves (figure 21) that are readily observed on its face. On the cliff face, the water grooves are up to 6 feet deep and offer some features for climbers to use on this otherwise featureless climbing face.

Figure 21. 1200 foot high face of Laurel Knob showing large water groves.

Until only recently, it was a very isolated location approachable only through a complex and unpleasant bushwack. As a result, only a handful of climbing routes were developed on the cliff due to the logistical challenges in climbing there. The early climbing routes followed obvious features, with the big right angling corner system that bisects the mountain being climbed first. Contemporaneous with the development of Lonesome Valley as a housing development below the cliff, in 2005 the Carolina Climbers Coaltion purchased Laurel Knob and now operate it as a climbing preserve, with access from the east through the USFS Panthertown Valley. Beyond a few cracks (unusual in Cashiers Valley), most climbing routes follow water grooves on the rock.

Following the visit to Laurel Knob return to Hwy 64 and head west back to Cashiers. At the intersection of Hwy 64 and 107 turn left on 107 (heading south) and retrace your path back to Clemson.

Acknowledgements

Invaluable assistance for this trip was provided by Mark Lassiter. His intimate knowledge of the area that is essentially his backyard (he lives in Whiteside Cove) and local connections expedited the planning process. Access to Lonesome Valley and the base of Laurel Knob was made possible by Mark. All of the climbing information was provided by Mark.

Access to the exclusive gated communities visited during this trip was provided by Bruce Kutt of Highlands Falls and David Cull of the Cullsaja Club. Lamar Hunt of the Highlands Town Hall provided access to the town quarry.

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